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ABSTRACT

This student module on fundamentals of electrical safety is one of 50 modules concerned with job safety and health. This module describes electricity and how it can affect the human body. Following the introduction, nine objectives (each keyed to a page in the text) the student is expected to accomplish are listed (e.g., Name five common electrical hazards). Then each objective is taught in detail, sometimes accompanied by illustrations. Learning activities are included. A list of references and answers to learning activities complete the module. (CT)

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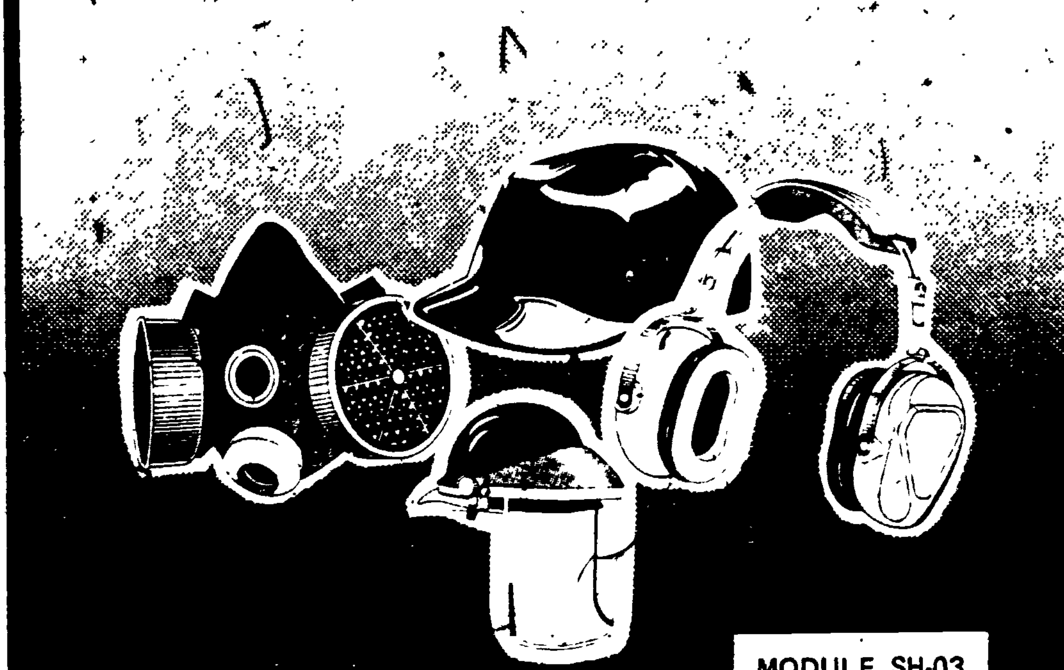
SAFETY AND HEALTH

FUNDAMENTALS OF ELECTRICAL SAFETY



MODULE SH-03

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INTRODUCTION

Electricity is our most versatile and widely used form of energy. Electricity lights our buildings and streets, heats and cools our homes and workplaces, provides a medium for communications and computers, and drives electric motors for machinery. Our society has advanced, industry has prospered, and the physical demands on workers have been reduced because we have put electricity to work for us.

However, when electricity is misused due to ignorance and disregard, or if an electrical tool or circuit malfunctions, electricity can become a deadly hazard. When electricity comes into direct contact with the human body, an injury or death may result. Electricity is only safe if it is used and controlled properly; it is not something to fear, but it should be respected. And, respect for electricity can only come from adequate knowledge and a healthy attitude about electrical safety.

This module describes electricity and how it can affect the human body. It identifies potential electrical hazards, safety devices, and procedures to follow that will reduce the possibility of an electrical accident.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Explain what electricity is. (Page 3).
2. Define voltage, current, resistance, and power. (Page 3)
3. Differentiate between conductors and insulators, and describe their functions. (Page 6)
4. Name the major components of an electric circuit, and major types. (Page 8).
5. Name five common electrical hazards. (Page 10)
6. Describe the body's reactions to electrical shock, and list the proper first aid procedures that should be applied in order of their importance. (Page 12)
7. State six OSHA requirements for electrical safety. (Page 17)

8. List and discuss at least five safety features available for electrical equipment. (Page 20)
9. List the prescribed OSHA rules to follow when using lockout procedures as a method of protection. (Page 28)

OBJECTIVE 1: Explain what electricity is.

In order to protect yourself from electrical hazards, you must first understand how electricity works: Electricity is a form of energy; it is tiny, charged particles, called electrons, that move in the same direction through a material. The electron – one of the basic building blocks of an atom – carries a negative electrical charge. Electrons can move in solids, liquids, or gases; and when a large number of them move together in the same direction at the same time, they create an electrical current.

ACTIVITY 1:

Circle the letter of the selection that best answers or completes the numbered statement or question.

1. Electricity is: (a) a form of work, (b) a form of energy, (c) a movement of atoms, (d) none of the above.
2. Electrons: (a) are smaller than the atom, (b) carry a negative electric charge, (c) are movable, (d) all of the above.

OBJECTIVE 2: Define voltage, current, resistance, and power.

Electrical current is electrons flowing in a material past a particular point in a given time; current is measured in AMPERES (represented by the symbol I). Electrical current flows through a material in a manner similar to water flowing through a pipe. The pressure that causes an electric current to flow is called VOLTAGE (represented by the symbol V). Some voltage sources are batteries, generators, and wall plugs.

When current flows through a material, there is an opposition to the flow, called RESISTANCE (represented by the symbol R). The resistance of materials varies according to the type of material, its size, and its shape.

The three fundamental quantities of electricity — current, voltage, and resistance — are shown symbolically in the circuit in Figure 1.

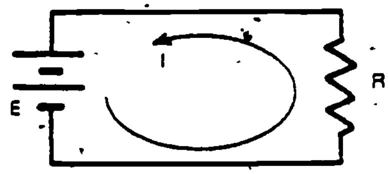

Figure 1. Electrical circuit for Ohm's law.

The relationship between these quantities is a simple equation called Ohm's law, which states that current (I) is directly proportional to the applied voltage (E) and is inversely proportional to the resistance (R). This means that, should the voltage across any material increase, then the current flowing through the material also would increase as long as the resistance of the material remained the same. And, if the voltage across two different resistances were the same, current would be the greatest through the smallest resistance. Ohm's law can be represented in a mathematical equation by use of the symbols I, E, and R (current, voltage, and resistance, respectively) in three different arrangements. The resulting three equations of Ohm's law are as follows:

$$E = I \times R \qquad \text{Equation 1}$$

$$I = E/R \qquad \text{Equation 2}$$

$$R = E/I \qquad \text{Equation 3}$$

Ohm's law equations allow us to determine the amount of any one of the quantities if we know the value of the other two. The following are example uses of Ohm's law.

1. Given: The toaster in the kitchen is attached to a voltage source that provides 120 volts and 8 amperes of current. Using $R = E/I$,

   Find: The resistance of the toaster.

   Solution: $R = E/I$

   $R = (120 \text{ volts})/(8 \text{ amperes})$

   $R = \underline{15 \text{ ohms}}$.

2. Given: The incandescent light bulb in a lamp has a resistance of 192 ohms and has 120 volts applied to it. Using I = E/R.

Find: The current flowing through the light bulb.

Solution: $I = E/R$

$I = (120 \text{ volts})/(192 \text{ ohms})$

$I = \underline{0.625 \text{ amperes}}$.

3. Given: A clock has a resistance of 7200 ohms, and a current of 0.016667 amperes is flowing through it. Using E = I x R,

Find: The voltage that is present across the clock.

Solution: $E = I \times R$

$E = (0.016667 \text{ amperes}) \times (7200 \text{ ohms})$

$E = \underline{120 \text{ volts}}$.

Two important facts about electricity are demonstrated by Ohm's law; they are:

1. Current will always flow through the pathway of the least resistance.
2. If there is enough voltage, there will be some current flow regardless of the amount of resistance present in a substance.

These facts bear heavily on a person's safety when we consider the effects of electricity.

To fully appreciate the effects of electricity in equipment and on the human body, we must examine one additional quantity — electrical power. You have noticed that light bulbs are available in different "wattages," and you know that a 100-watt light bulb provides more light than a 60- or 75-watt light bulb. The watt is the unit of measure for power, which is represented by the letter P. In simple resistance circuits such as for light bulbs, toasters, and heaters, power is the product of current and voltage and is calculated from the equation,

$$P = I \times E \qquad \text{Equation 4}$$

Thus, you can see that the light bulb in the second example use of Ohm's law above must have a power rating of 75 watts as shown in the following example.

Given: E = 120 volts, I = 0.625 amperes, and Equation 4.

Find: P

Solution: $P = I \times E$

$P = (0.625 \text{ amperes}) \times (120 \text{ volts})$

$P = 75 \text{ watts}.$

The effects of electricity are determined not only by the current flowing through a substance, but by the voltage applied across it, and the amount of power used by it. The effects of electricity that are most important to this module are those that result in hazards to human life and property.

ACTIVITY 2:

1. Match the term in Column A to the correct definition found in Column B by filling the blanks with the appropriate letters.

Column A		Column B
___ Voltage	a.	$I = E/R$
___ Power	b.	$R = I/E$
___ Current	c.	The force that causes electron flow
___ Resistance	d.	The directional flow of electrons
___ Ohm's law	e.	$I \times E$
	f.	The opposition of electron movement in a material

2. State Ohm's law.

____

____

____

OBJECTIVE 3: Differentiate between conductors and insulators, and describe their functions.

Some materials provide very little resistance to the flow of electrical current; these materials are called conductors. Examples of conductors are

metal wire and tubes, salty or dirty water, and ionized gases (such as in fluorescent lights).

Other materials have a very high resistance to the flow of electrical current; these materials are called insulators. Examples of good insulators are dry rubber, paper, leather, glass, and plastics. When insulators are wet (with water) they sometimes become good conductors. Air is usually a good insulator. When a wire in an electrical circuit is cut or broken and there is an air gap (one-half inch or more) between the ends of the wire, current will not flow in the circuit. However, if the wires are brought very close together, the electric current will "arc" across the remaining gap and current will flow through the air.

An electric switch is usually a mechanical device inserted into a circuit that has a closed (or ON) position and an open (or OFF) position. When the switch is closed, current flows through it; when the switch is open, an air gap separates two ends of a metal conductor and current will not flow in the circuit. Figure 2 shows a simple electrical circuit with a switch.

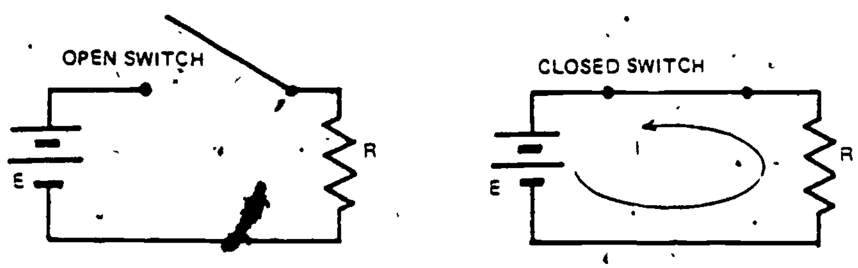

Figure 2. Circuit with switch.

A common example of where both insulators and conductors are used can be found in the ordinary electric cord. The copper wires in the cord are conductors through which electrons move. An insulating material, such as rubber, is wrapped around each wire to prevent electricity from flowing anywhere except along the conductors.

ACTIVITY 3:

Briefly define the following terms:

1. Conductor ______________________________
2. Insulator ______________________________

OBJECTIVE 4: Name the major components of an electrical circuit, and the major types.

Because electricity is so versatile there is not a single system or circuit that is representative of all electrical applications. However, all the circuits that exist can be classed into three categories. Furthermore, all circuits have three major components. These three components are:

- A source of electrical energy.
- A path formed by a conductor or conductors.
- A load (usually represented by a resistance) that converts the electrical energy into work.

When these three components are present, an electrical circuit exists. For the circuit to work, the energy source must provide a voltage to cause current to flow. As noted by Ohm's law, the greatest current will always flow through the conductor that presents the least resistance. These conditions are valid for both alternating current (a.c.) and direct current (d.c.) electrical circuits.*

A closed circuit is formed when there is a complete, unbroken path for the flow of current from the source to the load and back to the source. In a d.c. circuit this flow is always in one direction; in an a.c. circuit the direction changes back and forth. Because each closed circuit is the same (functionally) regardless of the type of electricity, all closed circuits can be represented by Figure 3.

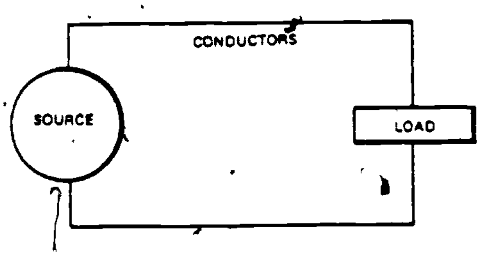

Figure 3. A closed circuit.

The opposite of a closed circuit is an open circuit. Current cannot flow in an open circuit because there is no complete pathway for energy to transfer from the source to the load and back

*"A.c. and d.c." refer to the two major types of electric current. D.c. is direct current — electron movement is in one direction. A.c. is alternating current — electron movement changes at regular intervals from one direction to the opposite direction. A battery is a source of d.c., and the wall outlet in your home is a source of a.c.

to the source. An open circuit can occur accidentally or by design. When a switch is placed in one of the conductive paths between the source and the load, it is possible to control whether the circuit is open or closed. When you turn on a radio, lamp, drill, or any electrical device, the switch closes an electrical circuit. When a lamp cord becomes frayed and one conductor is broken, or when the filament of a light bulb in the lamp breaks, the circuit has been opened accidentally.

A third type of circuit is a short circuit. The short circuit occurs when a path is introduced into a circuit that drastically (or significantly) lowers the total resistance of the circuit and diverts most of the current away from the intended load. The block diagram in Figure 4 shows a simple short circuit. The short circuit in Figure 4, although simple, represents the most serious type because the short reduces the apparent resistance of the circuit to nearly zero ohms, resulting in a very large current. Short circuits often occur accidentally and by different means, such as:

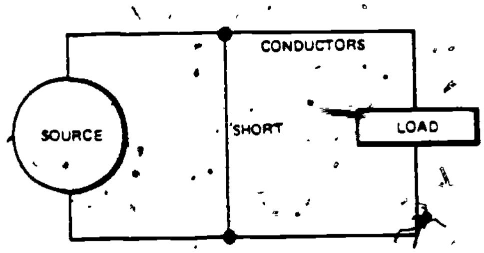

Figure 4. A short circuit.

1. The insulation separating the two conductors in a lamp cord breaks down and allows the two conductors to come in contact.
2. A glass of water is tipped over on top of a TV set; some of the water gets inside the power supply and shorts the two conductors of the high-voltage supply together.
3. A crane operator at a construction site accidentally swings the boom of the crane so that it comes into contact with the high-voltage line of the public service company.

In each of these situations, a low-resistance path is inserted into the circuit. The lower resistance provides a new path for current to return to the source, and more current is drawn from the source than its normal operation.

It cannot be overemphasized how easily and how quickly an open circuit can be changed to a closed circuit or to a short circuit by the breakdown of some insulation or the introduction of a new conductive path. The conductive path does not have to be metal; it can be moisture, vegetable matter, or a human body. The earth on which we stand can represent a conductive path to draw current from a circuit. Thus, if a conductive pathway is provided from a source of voltage to the earth, there will be current flow as if there were a simple closed circuit. Connecting a conductor from a load or source to the earth is called "grounding."

To be able to understand the hazards that exist with electricity and electrical circuits, it is very important to remember two basic facts.

1. When a circuit is "closed" and current flows, electrical energy is transmitted from the voltage source to the load (resistance).
2. All substances are potential conductors of electricity.

ACTIVITY 4:

(Briefly define the following terms.)

1. Closed circuit ____________________
   ____
2. Open circuit ____________________
   ____
3. Short circuit ____________________
   ____

OBJECTIVE 5: Name five common electrical hazards.

Electricity poses a wide number of hazards to both people and equipment. Electric shock is a major hazard — under certain conditions, electricity can cause severe burns and even death. The intensity and effects of shock depend on the path of the current, the amount of the current, and the length of time in contact with the current.

Industrial fires are another major electrical hazard. According to the National Fire Protection Agency and Factory Mutual, electrical ignition is the most common cause of industrial fires. Ignition of flammable materials

may occur due to defective or faulty wiring, insulation failure, motor troubles, or improper circuit breakers and switches. Insulation failure may result from misuse, overloading, aging, or attack by a foreign substance.

Another source of electrical hazard is the accidental starting of equipment. Besides encountering electrical shock from circuits that should have been left disconnected, persons have been injured by accidental starting of mechanical equipment like presses and conveyor belts when power was inadvertently restored. Proper controls on hazardous equipment and tagging switches to circuits that are to be disconnected remain the best ways to avoid this hazard.

The improper use of electrical equipment is another common electrical hazard. Persons who are to operate any electrical equipment should be instructed in its proper usage and care.

Because the use of electrical power creates heat due to resistance, overheating of equipment can produce a hazardous situation. Overheating can cause materials to reach their temperature of autoignition, ignite flammable vapors present, or cause equipment to fail. Overheating may also cause surfaces of equipment to become hot enough to cause thermal contact burns. Even common dry-cell batteries, used to power flashlights, portable radios, and camera flash attachments, can cause problems when improperly stored or carried. Any conductor accidentally placed into contact with both battery terminals could possibly produce enough heat to cause a burn or heat intense enough to start a fire. In one instance, a smoking nine-volt battery was removed from a purse, where, after having been removed from a portable radio and dropped into contact with coins in the change compartment, a short circuit occurred and produced enough heat to create a hazardous situation.

Many electrical incidents are caused by faulty or improperly used tools and equipment. Examples include worn or frayed power cords, removal of three-prong plugs, and an electrical short to the metal case of the equipment. A program for maintenance and inspection of electrical equipment would be helpful in avoiding potentially dangerous situations. An established testing program of electrical components will reveal problem areas in equipment, processes, or usage that can prevent serious incidents. Annual or semiannual inspection and testing of circuits and permanently mounted equipment, as well as more frequent testing of portable tools, cordsets, plugs, and so forth,

might be performed, depending upon frequency and type of usage.

ACTIVITY 5:

List five common electrical hazards.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

> **OBJECTIVE 6:** Describe the body's reactions to electrical shock, and list the proper first aid procedures that should be applied in order of their importance.

Accidents involving electricity occur every day. Approximately 1000 accidental electrocutions occur in the United States annually, with one-fourth being occupationally related. Additionally, thousands of other persons receive burns and other injuries as the result of unplanned contact with electricity.

Electrical shock is the sudden and accidental stimulation of the body's nervous system by an electric current. As stated previously, effects of electrical current depend upon the path of the current, the amount of current, and the length of time in contact with the current. A person can become a part of an electrical circuit by touching both ends of an open circuit at the same time, by contact with a short circuit, or by contact with a current-carrying conductor while in contact with ground (earth).

The effects of current on the human body range from a mild tingling sensation to death. Contact with current can cause severe muscular contractions strong enough to break bones, as well as deep tissue burns and heavy bleeding.

A commonly held misconception is that high voltage is more dangerous than low voltage. Low voltage (down to approximately 50 volts) can kill just as quickly as high voltage; severity of shock is dependent upon current. Less than one ampere of current can cause death because current flow is related to voltage and resistance; Ohm's law demonstrates that specific conditions at

the time of the incident determine the degree of hazard.

The current that flows through a body depends on the resistance between the body and the points of contact, as well as on the resistance of the body itself. Dry, clean, unbroken human skin has an electrical resistance of 100,000 to 600,000 ohms, depending on thickness. Wet or broken skin has a resistance of approximately 500 ohms. Thus, with the same voltage source one could receive 200 times more current with wet skin than with dry skin. If the current stays on the outside of the skin, a person may only receive minor burns, but if the current can penetrate the skin, the damage can be more serious.

Though current is the primary source of electrical damage to body tissue, the common 60-hertz a.c. line voltage provides a unique danger to the heart. Because 60 hertz is close to the frequency at which ventricular fibrillation of the heart often occurs, 60 hertz is more disruptive to the human nervous system than pure d.c. Ventricular fibrillation occurs when each individual muscle fiber of the heart contracts in an irregular, random twitching manner that results in no pumping of blood. The danger of ventricular fibrillation is far less with a.c. that is higher or lower than 60 hertz in frequency.

The effects of current, specifically 60 Hz a.c., on the human body can be better understood by examining the facts presented in Table 1.

TABLE 1
EFFECTS OF 60-HZ A.C. ELECTRICAL SHOCK

- 0.001 ampere — The shock is barely felt. The major hazard is high probability that the person will make a sudden, involuntary movement that will cause him or her to fall or to come into contact with something more hazardous.
- 0.002 to 0.025 amperes — Muscles will be paralyzed if the current path is through the body. With muscle control paralyzed, a person will be unable to break contact. Men's muscles become paralyzed at a minimum current of 0.009 amperes, and women's muscles become paralyzed at a minimum current of 0.006 amperes on the average.
- 0.025 to 0.075 amperes — The electrical shock can be very painful, and severe muscular contractions can occur that are strong enough to break bones. Prolonged contact will produce unconsciousness and death in approximately three minutes if paralysis of respiratory muscles occurs.

- 0.075 to 0.3 amperes — Death is a near certainty if exposure to this level of current extends to longer than one-quarter of a second.
- 2.5 amperes or greater — The heartbeat of a person exposed to this level of current will stop immediately, with severe tissue damage a certainty.

The internal resistance of the body also contributes to the potential severity of shock. Internal body resistance, due to the conductance of body fluids, may be 300 ohms for current flow from head to foot. The path of current is important when discussing shock damage. Most fatal electrical shocks travel through the heart. This means that hand to hand, either hand to the left foot, or head to foot shocks have the most potential for serious injury. (See Figure 5.)

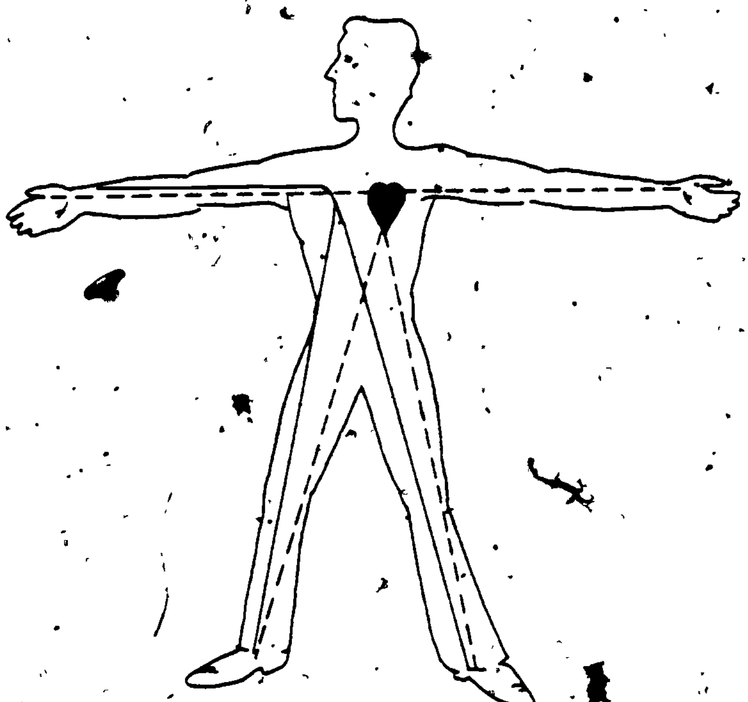

Figure 5. Fatal injuries can occur when shock current passes through your body.

There is little time to waste in the event of severe electrical shock. The victim should be removed from contact with the current as soon as possible, and in a manner that will not pose a shock hazard to the rescuer. If the victim is near or touching live wires, the wires should be removed with a dry, nonconducting object. If the power cannot be shut off, the victim should be pushed or dragged from contact with dry wood, rope, or other insulating materials. After the victim has been removed from contact with the electricity, call for medical help and begin first aid procedures immediately. Resuscitation efforts should always be attempted and continued. There is no way to tell what damage the victim has sustained, but efforts should be made to give

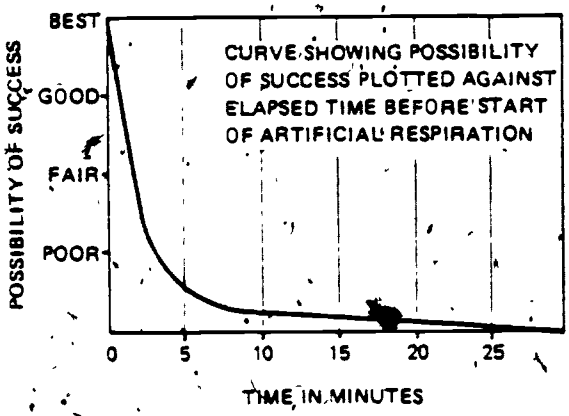

Figure 6. The possibility of successful revival decreases with time.

that person the best possible chance for survival. Figure 6 demonstrates the importance of beginning revival efforts immediately.

Detailed instruction in CPR (cardiopulmonary resuscitation) is beyond the scope of this module; it requires special training in the recognition of cardiac arrest and in the performance of CPR. Instruction includes practice of proper individual and team resuscitation of a special mannequin. CPR should be performed only by trained and certified persons. Training through the American National Red Cross is offered throughout the nation; a call to the local Red Cross chapter will place you in contact with those who can provide training in CPR and in mouth-to-mouth breathing, as well as other first aid procedures. The importance of receiving such training is that it can mean the difference between saving a life and letting a person die.

To perform first aid to a person who has come into contact with electricity and who is unconscious, the following steps must be taken:

1. Remove the person from contact with the current without coming into contact with it.
2. Check to see if the victim is breathing and if there is a heart beat present. If the person is not breathing, or is not breathing well, administer mouth-to-mouth breathing. If there is no pulse, administer CPR.
3. When the person is breathing on his or her own, check for other problems that may need immediate attention. If the person is bleeding excessively, stop the bleeding by use of pressure on the wound or on pressure points in major arteries or veins.
4. Determine severity of burns. Burns are common in electrical accidents and can be quite serious. Severity of burns is dependent upon depth, area, and location. The treatment required is different for each degree of severity, and the correct first aid procedure should be followed.
5. If there are any broken bones or severe sprains, the best idea is to immobilize the limb so that the break cannot experience motion and cause greater damage.

In addition to following the preceding steps, the person administering

first aid should check the victim for signs of physiological shock (not electrical shock). Shock results from the depression of vital body functions. It can be life-threatening even though the actual injury might not be fatal otherwise. Vital functions are depressed when a large amount of blood is lost, when the rate of blood flow is reduced, or when the oxygen supply is insufficient. Shock can be caused by any type of severe injury. Injury-related shock is different from electric shock. The symptoms of injury-related shock include pale (or bluish) skin, rapid pulse, and rapid breathing. The victim should be left lying down, and covered just enough to maintain the body temperature. Medical help should be obtained as soon as possible.

This objective has shown what happens when the body is exposed to electric current, what should be done for a victim of accidental electrical contact, and what order should be followed. Obtaining the information and training necessary to be effective in giving first aid is available; either through one's employer, the YMCA, the YWCA, or the American Red Cross.

ACTIVITY 6:

1. Identify the three greatest dangers that can arise from accidental contact with electric current.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. Number the following results of electrical shock and the order in which they should be treated to save the victim's life.

   ___ Shallow cut to arm.
   ___ Burns on hand.
   ___ No heart beat.
   ___ Deep cut on thigh, with severe bleeding.
   ___ Rapid pulse and breathing.
   ___ Broken leg.
   ___ Severe burns on head and neck.
   ___ Person cannot breathe on own.

OBJECTIVE 7: State six OSHA requirements for electrical safety.

The Occupational Safety and Health Administration (OSHA) has determined that electrical hazards in the workplace create significant risk of injury or death for employees and that regulations are necessary to provide protection from these hazards. OSHA has revised the electrical standards found in Subpart S of 29 CFR Part 1910 and incorporated requirements from the National Electric Code.

To be approved by OSHA, electrical equipment and conductors must be acceptable to the Assistant Secretary of Labor. To be acceptable, equipment must be either:

1. Accepted, certified, listed, labeled, or otherwise determined to be safe by a nationally recognized testing laboratory (such as Underwriters' Laboratories, Inc., Factory Mutual Engineering Corp., or so forth).
2. Found in compliance with the National Electric Code by a government agency responsible for enforcing the Code.
3. Determined to be safe for its intended use by its manufacturer on the basis of test data kept by the employer and available for inspection by the Assistant Secretary or his authorized representatives.

OSHA has several requirements to increase electrical safety. These requirements include the use of interlocks, physical barriers, guards, and warning signs on machinery; isolation of high-voltage equipment; and routine inspections.

Interlocks are circuit switches installed on a panel, door, etc., of an enclosure. When the enclosure is opened, the circuit is de-energized because the circuit is broken. Interlocks should be provided to interrupt power when access to energized equipment interiors may occur. The interlock should be fail-safe. This means that failure of the interlock mechanism, loss of power, short-circuit, or malfunction of equipment must cause the interlock to interrupt the circuit — despite these conditions, the interlock should continue to function and, therefore, protect. The interlock also should provide a visible disconnection in the primary power circuit and an arrangement that makes any attempt to override or circumvent the interlock impractical. Interlocks should never be removed, modified, or tampered with.

Physical barriers prevent accidental contact with equipment. Barriers

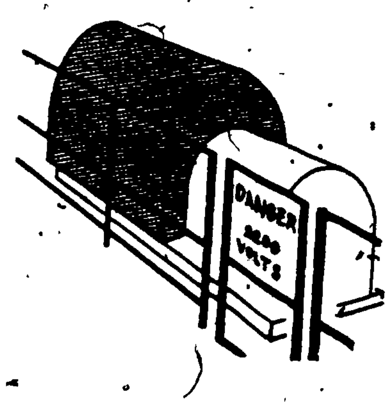

Figure 7. Guards and barriers prevent accidental contact with energized equipment.

may be made of any number of materials. Although wood is flammable, it is nonconductive, as are certain plastics. Barriers may be metal, metal mesh, wood, plastic, or any combination of these materials. Guards on machinery will allow sufficient access to equipment while preventing contact with energized parts. No machinery should be operated with guards removed or modified. Figure 7 illustrates the use of guards and barriers.

Warning signs should be large, easily read, and visible from all approaches to danger. They should be placed at all hazardous and dangerous areas such as high-voltage equipment or exposed, current-carrying parts. In addition, marking of points of access to hazardous equipment should be made obvious.

Isolation of equipment will prevent untrained or unauthorized persons from coming into contact with hazardous equipment. Fenced areas, for example, prevent unauthorized persons from contact with large electrical transformers. Large motors, generators, bus bars, and panels should be enclosed by some isolating means. All uninsulated conductors should be in vaults, or should be enclosed by some other type of security. Access should be by trained personnel only. Doors and gates should be locked, and only electrical technicians or persons familiar with the hazards involved should have access to keys.

Implementing and following all requirements stated by OSHA may not be enough. With natural wear and tear on equipment and the effects on equipment from the environment and time, hazards can develop unnoticed. For this reason, it is important that all electrical tools and equipment be inspected at regular intervals by persons qualified to recognize and correct hazards. The dedicated maintenance person is indispensible to this step. Table 2 is a check list for inspection of hazards in electrical equipment.

TABLE 2. INSPECTION OF ELECTRICAL EQUIPMENT.

CHECK WIRING FOR:

( ) Electrical installations in hazardous areas not conforming to codes.
( ) Damp or wet wires.
( ) Splashing of corrosive solutions and vapors on wires.
( ) Oil or grease on wiring.
( ) Broken fittings and enclosures.
( ) Weakened insulation.
( ) Weak armored cable attachment to switch boxes.
( ) Absence of protective busing when open wires enter boxes.
( ) Wear on drop cords of pendant lamps.
( ) Cables grouped in a junction box, pull box, cableway, trench, manhole, without protection or safeguards.
( ) Presence of abrasive and conducting dusts, or metallic chips, on equipment
( ) Insulated wiring that feels warm to the hands when a current is passing through.
( ) Installation of new current drains without compensating with heavier wiring.

CHECK MOTORS AND GENERATORS FOR:

( ) Overloading.
( ) Too frequent starting and jogging, or similar misuse.
( ) Dirt-clogged ventilating spaces.
( ) Single-phasing due to poor contacts in motor controllers or a blown fuse in a three-phase supply circuit.
( ) Dirt, oil, moisture, old age, or mechanical damage that can cause winding failures.
( ) Improper motor alignment.
( ) Excessive vibration.
( ) Worn insulation or oil-soaked insulation.
( ) Sparks from commutator-type motors.
( ) Absence of protective fuses, circuit breakers, thermal overload relays.

CHECK SWITCHES AND CONTROLLERS FOR:

( ) Loose connections at terminals that may cause overheating and arcing.
( ) Loose parts that may cause short circuits or grounds.
( ) Excessive arcing due to burned contacts or to low or dirty oil in switches, circuit breakers, and starting compensators.
( ) Short circuits due to leakage of water, oil, or conductive dusts into switch enclosures.
( ) Use of ordinary switches where explosionproof or intrinsically-safe switches are required.
( ) Inadequate interruptive capacity.
( ) Unprotected, poorly-fitting, or damaged covers on explosionproof enclosures, missing knockouts in switch enclosures.
( ) Severe vibration causing loose connections.
( ) Absence of tight-fitting covers secured by hasps, locks, or other means.
( ) Unusual noises from a switch, or a switch or junction box that feels warm to the hands

CHECK LAMPS, ELEMENTS, TRANSFORMERS FOR.

( ) Absence of wire guards on electric lamps, when lamps could come in contact with combustibles or might be easily broken by physical contact.
( ) Failure to use explosionproof gloves in combustible vapor areas.
( ) Failure to use dustproof outer gloves in areas of combustible dusts.
( ) Inadequate insulation of portable grills, ranges, industrial ovens.
( ) Overheated ballast units of fluorescent lights.
( ) Other overheated transformers.

CHECK PLANT VEHICLES FOR:

( ) Loose wiring connections.
( ) Deteriorated insulation.
( ) Defective switches.
( ) Defective barriers.

OTHER ELECTRICAL HAZARDS TO CHECK FOR

( ) Fuse bridging.
( ) Fuses rated too high for the load.
( ) Periodic cleaning of air filter plates and oil tanks not performed on electrostatic air cleaning equipment.
( ) Work coming in contact with or coming too close to the charged electrodes of electrostatic paint spraying equipment.

ACTIVITY 7:

State six OSHA requirements for electrical safety.

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______

OBJECTIVE 8: List and discuss at least five safety features available for electric equipment.

Due to our increased awareness of how people suffer accidents with electrical equipment, manufacturers have adopted many features that can lessen risks of exposure to hazards. Some of these features include specially designed receptacles and plugs, extension cords designed for specific uses, bonding, double insulation, explosion-proof switches and lights, circuit breakers, and color coding of wires.

Industry and many domestic applications of electrical energy require different voltages and currents; therefore, a piece of equipment rated for one voltage and current should not be plugged into a higher voltage or current capacity power system. To avoid or at least minimize just such an occurance, unique ~~plugs and~~ receptacles have been designed for different voltages and current capacities. Figure 8 shows a partial assortment of the most common plugs and receptacles as configured by the National Electrical Manufacures Association (NEMA). It is recommended that both plugs and receptacles undergo periodic inspection and testing to disclose any problems that may have developed due to wear and tear or possible errors in rewiring. It is not sufficent to visually inspect plugs or receptacles, especially in the instances where there is a grounding wire. Check the ground pin on receptacles for effectiveness by seeing if a closed circuit can be formed between a known ground (such as a water pipe) and the ground pin of the receptacle.

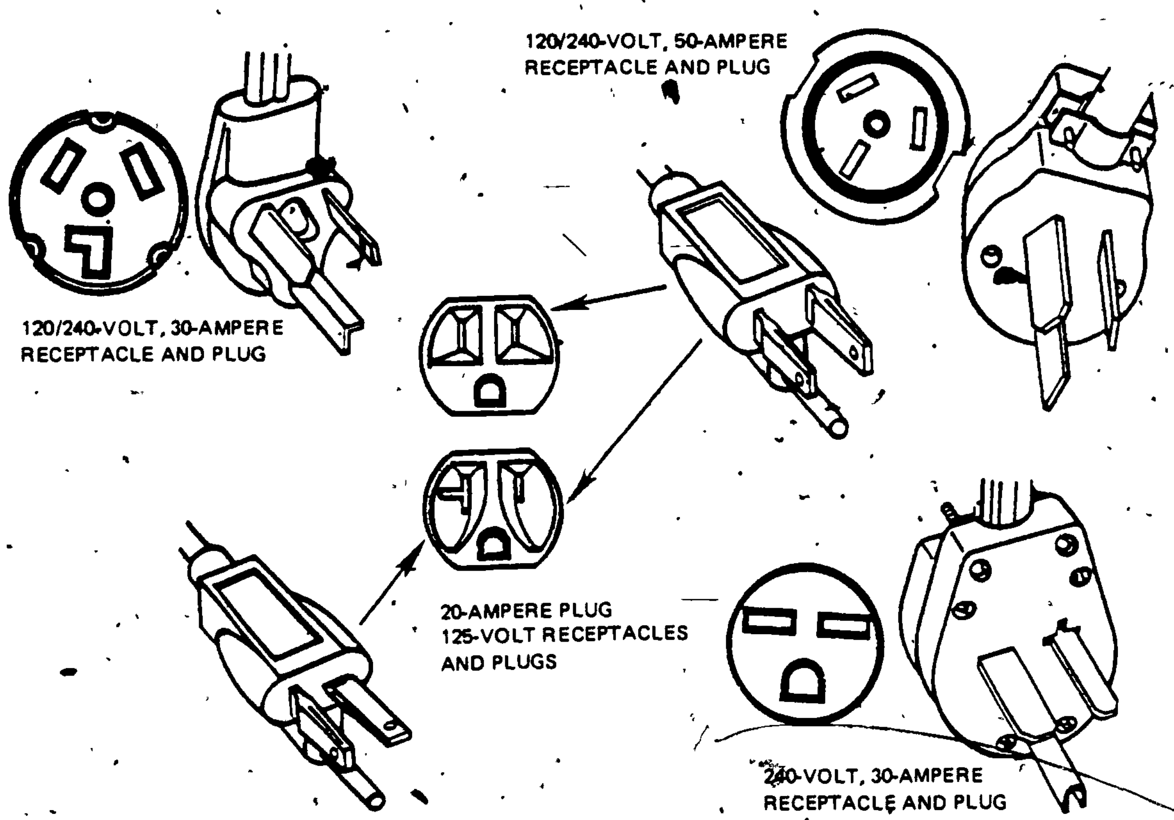

Figure 8. Receptacles and plugs with NEMA configurations.

To enable one to identify individual wires and pins in approved commercial and residential wiring, the use of a standardized color code has been widely adopted. This standardized color code, when applied, will properly identify the "hot" (voltage-carrying), neutral, and ground wires found in commercial and residential installations. Red or black is generally the hot wire, which is the conductor that supplies the highest voltage from the source. White or grey denotes the neutral wire, which is the conductor that provides the return path to the source and may carry a much lower voltage. Green or green with yellow stripes denotes the grounding conductor, which is connected to a local highly reliable ground. Approved household wiring is governed by the National Electric Code; in this system black is the hot wire, white is the neutral, and green is always the safety conductor.

In addition to following color coding, manufacturers of electrical plugs and receptacles have agreed that certain positions will be standardized for placement of the hot, neutral, and ground wires. Figure 9 illustrates the

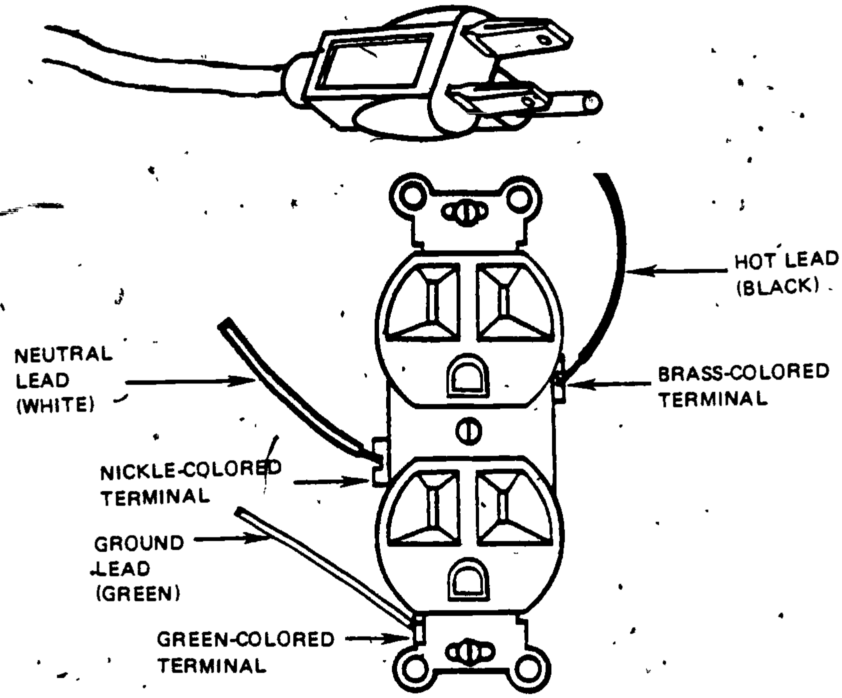

Figure 9. Common house plug and receptacles.

standard position of these wires in the normal house receptacles and plug. In addition to this placement it is common practice to make the neutral wire pin and slot in the receptacle larger than the hot wire pin as also shown in Figure 9.

Extension cords are so common that everyone should be familiar with the safety procedures for using them. Only approved extension cords should be used. To prevent the wire strands from breaking, an effort should be made to avoid kinks or unnecessary bending of the cord. Broken wires can pierce the insulation and become a shock or short-circuit hazard. Extension cords are designed for specific purposes, and it is necessary to use the correct cord for a particular usage. An extension cord must also be suitable for use under specific environmental conditions. Regular inspection is necessary to detect any cracks or breaks in the insulation.

The third wire seen in the cord plugs and receptacles prescribed today versus the two wire cords of some years in the past is for the specific purpose of providing a ground path from electrical appliances or tools. This wire

carries no current except in the case of an accidental short circuit in the device. The ground wire is connected to the metal case of the device. Thus, if the neutral wire happens to open and a hot conductor makes contact with the case, there is a low resistance conductive path to carry the current, protecting the user.

Grounding not only provides a means of carrying potentially harmful current away from an unintended path, such as a person. It also lessens the chance of accidental arcing. In the presence of flammable liquids or vapors, an electric arc or spark is most dangerous. An arc or spark will occur whenever the difference in electric voltage between two conductors is such that a conductive path can be created through the insulating material separating them. If this difference in pressure can be prevented, no spark will occur. The source of the electric voltage is most often from static electricity. It is produced by two materials rubbing together or flowing past one another. Connecting a ground wire from a metal container to a water pipe or a grounding rod assures that no static charge or electric voltage difference can exist between the container and ground. When transferring flammable substances from one metallic container to another, it is common practice to ground one container and then connect the other container to the first. This is called bonding. Examples of grounding and bonding with respect to flammable liquid tanks are shown in Figure 10.

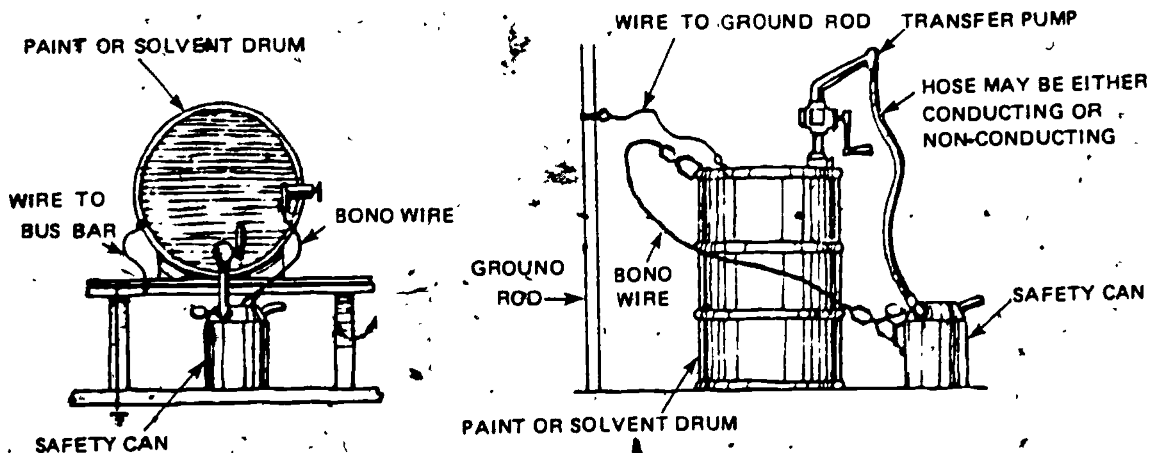

Figure 10. Grounding and bonding of flammable liquid tanks.

To be effective there must be adequate metal-to-metal contact for grounding or bonding. Surfaces of drums or cans with a heavy coat of paint or other material will not allow an adequate bond, since the coating acts as an insulator. Although grounding will not be effective in all cases, it is recommended that all equipment containing flammable liquids or vapors be electrically grounded, especially at points of transfer from one container to another.

Portable tools and appliances can be brought today that do not have a third wire ground. These devices must be protected by an approved system of double insulation. Tools in this category are marked with the words "double insulated," and those devices that have been tested and listed with Underwriters' Laboratories will carry the UL label. Some U.S. manufacturers will use the international symbol for double insulation . All electrical tools, equipment, and appliances have functional insulation; double insulated tools have protective insulation which protects the user should the functional insulation fail.

Double insulation isolates the energized parts of the tool or appliance by a nonconductive liner. These isolated parts are enclosed in a nonconductive case also. Double insulated or all-insulated tools do not require separate ground connections due to the low probability of both systems of insulation failing at the same time. Figure 11 shows a drill with double insulation.

Most people recognize the hazard involved in allowing electrical sparks, arcs, or overheated conductors to come in contact with air filled gasoline vapors or gases like propane, hydrogen, or natural gas. However, it is less common for people to realize that air filled with fine dust or lint is just as dangerous under the same circumstances. In any situation where there is a likelihood of flammable gases, vapors, dusts, or other easily ignitable materials being present, it is important that the electrical equipment be explosion proof.

Explosion-proof equipment is made of heavy cast materials designed to withstand high internal pressures without bursting and loosening, and they must provide good thermal insulation between the internal circuitry and the outside atmosphere. There should be no way in which any electric spark or arc can cause ignition outside the equipment. Due to the highly technical nature of the equipment and its selection for such environments, it is important that competent engineers conduct the selection and installation of the

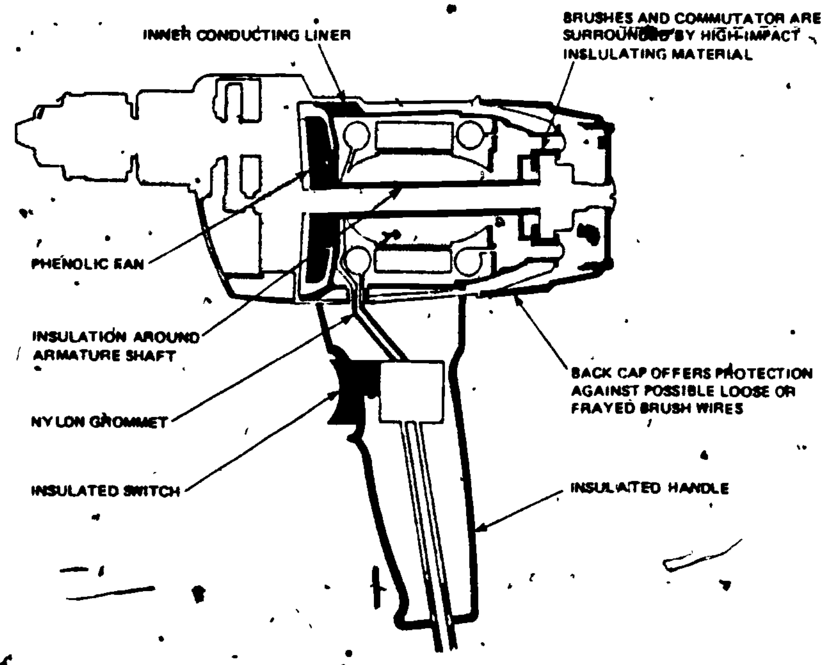

Figure 11. Double insulation.

explosion proof equipment. An explosion proof switch box is shown in Figure 12. Examples of explosion proof equipment can be found at flour mills, grain silos, textile factories, and refineries, to name a few locations.

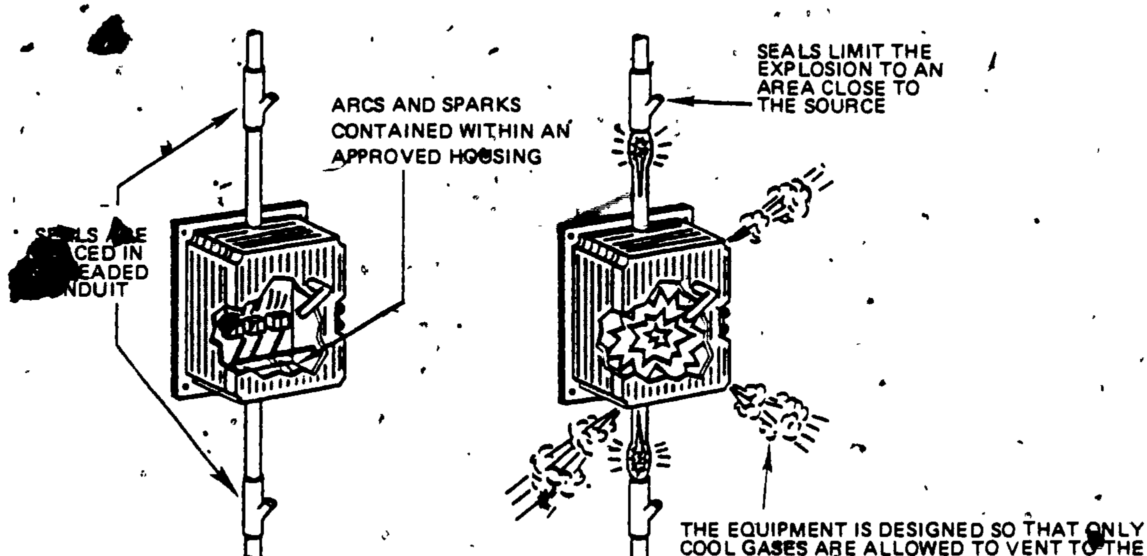

Figure 12. Explosion proof equipment.

Electricity has been shown to move in closed circuits. If the circuit is interrupted, current ceases to flow. In the case of an overloaded or short circuit, overcurrent devices protect personnel and equipment from damage by interrupting the circuit. The major types of overcurrent devices are fuses and circuit breakers. Each device has its own application and reacts to its own special set of circumstances, but all act to open the circuit and thus stop current flow.

Fuses are either renewable or nonrenewable and come in different types. Two types are shown in Figure 13. Fuses are constructed so that the current

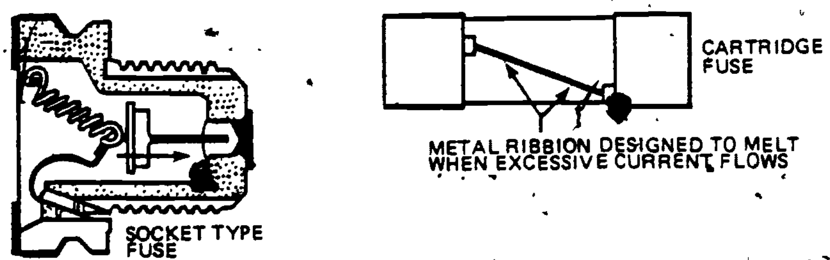

Figure 13. Common types of fuses.

in the circuit must flow through a metal strip which will melt at some temperature and then open the circuit. Every conductor has some resistance and heat is generated when current flows through a resistance. The metal strip in a fuse is of a type of material and of such a size that if more than a desired amount of current flows through it, enough excess heat is generated to melt the strip. After a fuse opens, the proper procedure for replacing the fuse is as follows:

- Deactivate the circuit which has the open or blown fuse; i.e., turn the power off.
- Remove the fuse using insulated fuse pullers.
- Replace the fuse with the same size and type of good fuse, being sure that the current ratings of the new fuse is the same as the old fuse.

Another type of device that is commonly used for protection from over current situations is the circuit breaker. There are two general types of

circuit breakers: thermal and magnetic. Both types are designed so that when more than a specific amount of current flows in the circuit, a pair of switch contacts open and current stops flowing in the circuit. The circuit breaker is prefered in many circumstances over the fuse because the breaker can be reset after a delay. Circuit breakers are designed for many different circuit conditions and should be selected on the basis of these conditions by qualified engineers and checked by experienced maintenance personnel to make sure they are in good operating condition at all times.

In addition to overcurrent protection devices (fuses and circuit breakers) the ground fault circuit interrupter (GFCI) is used in many circuits. The GFCI detects current leakage to ground well below the level of human sensation and when detected interrupts current flow. In hazardous locations such as construction sites and swimming pools it is recommended that GFCIs be employed. The interrupters can detect insulation failures as well as connections between hot connectors and ground; however, they cannot provide protection in the event that a person makes contact between a hot line and a neutral line.

Whenever current is interrupted by one of the three devices previously discussed, such interruption is an indication that there is something wrong with the circuit affected. It is important that this circuit be de-energized and kept de-energized until the trouble has been located and corrected. A procedure for keeping the circuit safely de-energized is discussed in the next section.

ACTIVITY 8:

(Circle the letter of the best answer.)

1. To prevent the accidental connection of low voltage equipment to high voltage sources, plugs and receptacles are:

   a. Color coded to indicate the voltage level.

   b. Indexed by placement, size, and shape of conductor pins and slots.

   c. Both a and above.

   d. None of the above selections.

2. To prevent the build up of static electric charges on containers of flammable substances and to protect against sparks transferring from one container to another it is common practice to use:
   a. Grounding.
   b. Bonding.
   c. Insulating.
   d. Both grounding and bonding.
3. According to the National Electric Code, the color of wire in housewiring used to designate the hot conductor lead is:
   a. White.
   b. Green.
   c. Grey.
   d. Black.
4. Circuit breakers and fuses are devices that:
   a. Detect current leakage to ground and open the circuit.
   b. Isolate a person from current sources.
   c. Interrupt current flow when that current flow is greater than a specified amount.
   d. Are used in atmospheres of flammable substances.
5. Double insulated electrical devices:
   a. Do not need the additional ground wire.
   b. Have functional insulation.
   c. Have protective insulation.
   d. All of the above.

OBJECTIVE 9: List the prescribed OSHA rules to follow when using lockout procedures as a method of protection.

As mentioned in the previous section, when protective devices such as a GFCI, circuit breaker, or fuse are activated and a circuit is opened, it

indicates that there is a hazardous condition existing in the circuit that requires attention. The trouble may be as simple as too many devices being operated off the same supply circuit, or it may be as complex as a concealed malfunction in a receptacle or in some device. It does not make any difference what the trouble is; it is important that maintenance personnel be informed and that the circuit be inspected. To inspect the circuit with the maximum degree of protection, it is important that the circuit be open so that no current is flowing. In industrial and residential situations it is important that a procedure be adopted that ensures that once a circuit is de-energized it stays de-energized until it has been inspected, and the trouble is corrected. To ensure that a circuit being inspected stays de-energized, OSHA recommends that a lockout procedure be adopted. The basic operating rules for this procedure are as follows:

1. The circuit that is to be worked on has its power switch padlocked in the off position.
2. The circuit is tagged with information as to who is working on the circuit, the type of work being performed, the date, and the department performing the work.
3. There is only one key to the padlock and it is in the possession of the person working on the circuit.
4. If there are numerous people working on the same circuit for different reasons a multiple padlock hasp is employed so that each section performing the needed work is protected. Figure 14 shows an example of just such a hasp.

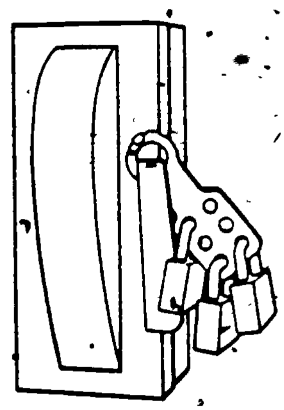

Figure 14. Multiple lockout hasp.

Accidental or unexpected activation of circuits can be avoided by training persons to strictly follow lockout procedures.

ACTIVITY 9:

(Answer each question as briefly as possible.)

1. Why isn't it enough to put a sign on a circuit power switch when working on a circuit?

   ____

   ____

2. Why should only one key to a lockout padlock be in existence? ______________________________

   ____

3. Why would a person want to have the only key to a lockout padlock if he were the person working on a circuit? ______________________________

   ____

   ____

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ANSWERS TO ACTIVITIES

ACTIVITY 1

1. b.
2. d.

ACTIVITY 2

1. Conductors are substances in which free electrons are easily formed and will flow readily through the material.
2. Insulators are substances in which free electrons are not formed easily and flow is difficult.

ACTIVITY 3

1. Column A

   c. Voltage

   e. Power

   d. Current

   f. Resistance

   a. Ohm's law

2. Current is directly proportional to the applied voltage and is inversely proportional to the resistance.

ACTIVITY 4

1. A circuit which provides an unbroken path of current flow from the source to the load and back to the source.
2. A circuit which has a source, load, and conductors but one in which there is a break in the conductive pathway that prevents the flow of current.
3. A circuit formed when an alternate pathway of current flow is introduced in such a way that less current than before flows through the load.

ACTIVITY 5

1. Improper use of equipment.
2. Accidental activation of equipment.
3. Overheating of electrical equipment.
4. Fire caused by electrical ignition.
5. Electric shock.

ACTIVITY 6

1. a. Heart stoppage.
   b. Stoppage of breath.
   c. Burns.
2. 8 Shallow cut on arm.
   7 Burns on hand.
   2 No heart beat.
   3 Deep cut in thigh, with a lot of bleeding.
   1 Person cannot breath on own.
   5 Rapid pulse and breathing.
   6 Broken leg.
   4 Severe burns on head and neck.

ACTIVITY 7

1. Use of interlocks.
2. Use of physical barriers.
3. Use of guards.
4. Use of warning signs.
5. Isolation of high voltage equipment.
6. Routine inspections.

ACTIVITY 8

1. b.
2. d.
3. d.
4. c.
5. d.

ACTIVITY 9

1. There is no certainty that the sign will not be removed accidentally or on purpose, nor is there any guarantee that another person will read or comply with the sign.

2. This ensures that the person who puts the padlock on the lockout is the one who takes it off and no one else can activate the circuit in between times.

3. This would remove or minimize the possibility of the circuit being energized while someone is working on it.